الطيران المدني
Civil Aviation
الإدارة العامة للطيران المدني - دولة الكويت
Directorate General of Civil Aviation - State of Kuwait

Kuwait Civil Aviation Safety Regulations

KCASR 5 – UNITS OF MEASUREMENT TO BE USED IN AIR AND GROUND OPERATIONS

Table of Contents

Table of Contents……...2

Amendment Record……...3

Chapter 1. Definitions……4

Chapter 2. Applicability……6

2.1 Applicability……..6

Chapter 3. Standard Application of Units of Measurement……..7

3.1 SI unit……7

3.2 Non-SI unit……...8

3.3 Application of Specific units…….. 8

Chapter 4. Termination of use of non-SI Alternative Units..…… 13

Attachment-A Development of the International System of Units (SI)……..……... 14

Attachment-B Guidance on the Application of the SI..…… 17

Attachment-C Conversion Factors…… 25

Attachment-D Coordinated Universal Time……..……... 34

Attachment-E Presentation of Date and Time in all-numeric form..……..…… 35

Amendment Record

Amendment No	Date of Issue	Remarks
1	June 2018	Part Rename

CHAPTER 1. DEFINITIONS

When the following terms are used in the Standards and Recommended Practices concerning the units of measurement to be used in all aspects of international civil aviation air and ground operations, they have the following meanings:

Ampere (A). The ampere is that constant electric current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in a vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length.

Becquerel (Bq). The activity of a radionuclide having one spontaneous nuclear transition per second.

Candela (cd). The luminous intensity, in the perpendicular direction, of a surface of 1/600000 square metre of black body at the temperature of freezing platinum under a pressure of 101325 newtons per square metre.

Celsius temperature ($t°_C$). The Celsius temperature is equal to the difference $t°_C = T - T_0$ between two thermodynamic temperatures T and T_0 where T_0 equals 273.15 kelvin.

Coulomb (C). The quantity of electricity transported in 1 second by a current of 1 ampere.

Degree Celsius (°C). The special name for the unit kelvin for use in stating values of Celsius temperature.

Farad (F). The capacitance of a capacitor between the plates of which there appears a difference of potential of 1 volt when it is charged by a quantity of electricity equal to 1 coulomb.

Foot (ft). The length equal to 0.3048 metre exactly.

Gray (Gy). The energy imparted by ionizing radiation to a mass of matter corresponding to 1 joule per kilogram.

Henry (H). The inductance of a closed circuit in which an electromotive force of 1 volt is produced when the electric current in the circuit varies uniformly at a rate of 1 ampere per second.

Hertz (Hz). The frequency of a periodic phenomenon of which the period is 1 second.

Human performance. Human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations.

Joule (J). The work done when the point of application of a force of 1 newton is displaced a distance of 1 metre in the direction of the force.

Kelvin (K). A unit of thermodynamic temperature which is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

Kilogram (kg). The unit of mass equal to the mass of the international prototype of the kilogram.

Knot (kt). The speed equal to 1 nautical mile per hour.

Litre (L). A unit of volume restricted to the measurement of liquids and gases which is equal to 1 cubic decimetre.

Lumen (lm). The luminous flux emitted in a solid angle of 1 steradian by a point source having a uniform intensity of 1 candela.

Lux (lx). The illuminance produced by a luminous flux of 1 lumen uniformly distributed over a surface of 1 square metre.

Metre (m). The distance travelled by light in a vacuum during 1/299792458 of a second.

Mole (mol). The amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon-12.

Note.- *When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles or specified groups of such particles.*

Nautical mile (NM). The length equal to 1852 metres exactly.

Newton (N). The force which when applied to a body having a mass of 1 kilogram gives it an acceleration of 1 metre per second squared.

Ohm (Ω). The electric resistance between two points of a conductor when a constant difference of potential of 1 volt, applied between these two points, produces in this conductor a current of 1 ampere, this conductor not being the source of any electromotive force.

Pascal (Pa). The pressure or stress of 1 newton per square metre.

Radian (rad). The plane angle between two radii of a circle which cut off on the circumference an arc equal in length to the radius.

Second (s). The duration of 9192631770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom.

Siemens (S). The electric conductance of a conductor in which a current of 1 ampere is produced by an electric potential difference of 1 volt.

Sievert (Sv). The unit of radiation dose equivalent corresponding to 1 joule per kilogram.

Steradian (sr). The solid angle which, having its vertex in the centre of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere.

Tesla (T). The magnetic flux density given by a magnetic flux of 1 weber per square metre.

Tonne (t). The mass equal to 1 000 kilograms.

Volt (V). The unit of electric potential difference and electromotive force which is the difference of electric potential between two points of a conductor carrying a constant current of 1 ampere, when the power dissipated between these points is equal to 1 watt.

Watt (W). The power which gives rise to the production of energy at the rate of 1 joule per second.

Weber (Wb). The magnetic flux which, linking a circuit of one turn, produces in it an electromotive force of 1 volt as it is reduced to zero at a uniform rate in 1 second.

CHAPTER 2. APPLICABILITY

Introductory

Note:- *This Regulation contains specifications for the use of a standardized system of units of measurement in international civil aviation air and ground operations. This standardized system of units of measurement is based on the International System of Units (SI) and certain non-SI units considered necessary to meet the specialized requirements of international civil aviation. See Attachment A for details concerning the development of the SI.*

2.1 Applicability

The Standards and Recommended Practices contained in this Annex shall be applicable to all aspects of international civil aviation air and ground operations.

CHAPTER 3. STANDARD APPLICATION OF UNITS OF MEASUREMENT

3.1 SI units

3.1.1 The International System of Units developed and maintained by the General Conference of Weights and Measures (CGPM) shall, subject to the provisions of 3.2 and 3.3, be used as the standard system of units of measurement for all aspects of international civil aviation air and ground operations.

3.1.2 Prefixes

The prefixes and symbols listed in Table 3-1 shall be used to form names and symbols of the decimal multiples and sub-multiples of SI units.

***Note 1**: As used herein the term SI unit is meant to include base units and derived units as well as their multiples and sub-multiples.*

***Note 2:**See Attachment B for guidance on the general application of prefixes.*

Table 3-1. SI unit prefixes

Multiplication factor		*Prefix*	*Symbol*
1000000000000000000	$= 10^{18}$	exa	E
1000000000000000	$= 10^{15}$	peta	P
1000000000000	$= 10^{12}$	tera	T
1000000000	$= 10^{9}$	giga	G
1000000	$= 10^{6}$	mega	M
1000	$= 10^{3}$	kilo	k
100	$= 10^{2}$	hecto	h
10	$= 10^{1}$	deca	da
0.1	$= 10^{-1}$	deci	d
0.01	$= 10^{-2}$	centi	c
0.001	$= 10^{-3}$	milli	m
0.000 001	$= 10^{-6}$	micro	µ
0.000000001	$= 10^{-9}$	nano	n
0.000000000001	$= 10^{-12}$	pico	p
0.000000000000001	$= 10^{-15}$	femto	f
0.00000000000000000	$= 10^{-18}$	atto	a

3.2 Non-SI units

3.2.1 Non-SI units for permanent use with the SI

The non-SI units listed in Table 3-2 shall be used either in lieu of, or in addition to, SI units as primary units of measurement but only as specified in Table 3-4.

Table 3-2. Non-SI units for use with the SI

Specific quantities in Table 3-4 related to Unit		*Symbol*	*Definition (in terms of SI units)*
Mass	tonne	t	1 t = 10^3 kg
plane angle	degree	°	1° = (π/180) rad
	minute	'	1' = (1/60)° = (π/10 800) rad
	second	"	1" = (1/60)' = (π/648 000) rad
Temperature	degree Celsius	°C	1 unit °C = 1 unit K[a)]
Time	minute	min	1 min = 60 s
	hour	h	1 h = 60 min = 3 600 s
	day	d	1 d = 24 h = 86 400 s
	week, month, year	—	
Volume3	litre	L	1 L = 1 dm^3 = $10^{-3}m^3$

a) See Attachment C, Table C-2 for conversion.

3.2.2 Non-SI alternative units permitted for temporary use with the SI

The non-SI units listed in Table 3-3 shall be permitted for temporary use as alternative units of measurement but only for those specific quantities listed in Table 3-4.

Note.- It is intended that the use of the non-SI alternative units listed in Table 3-3 and applied as indicated in Table 3-4 will eventually be discontinued in accordance with individual unit termination dates established by the Council. Termination dates, when established, will be given in Chapter 4.

3.3 Application of specific units

3.3.1 The application of units of measurement for certain quantities used in international civil aviation air and ground operations shall be in accordance with Table 3-4.

Note.- Table 3-4 is intended to provide standardization of units (including prefixes) for those quantities commonly used in air and ground operations. Basic Annex provisions apply for units to be used for quantities not listed.

3.3.2 **Recommendation.-** *Means and provisions for design, procedures and training should be established for operations in environments involving the use of standard and non-SI alternatives of specific units of measurement, or the transition between environments using different units, with due consideration to human performance.*

Note.- Guidance material on human performance can be found in the Human Factors Training Manual *(Doc 9683).*

Table 3-3. Non-SI alternative units permitted for temporary use with the SI

Specific quantities in Table 3-4 related to	*Unit*	*Symbol*	*Definition (in terms of SI units)*
distance (long)	nautical mile	NM	1 NM = 1 852 m
distance (vertical)[a)]	foot	ft	1 ft = 0.304 8 m
speed	knot	kt	1 kt = 0.514 444 m/s

a) altitude, elevation, height, vertical speed.

Table 3-4. Standard application of specific units of measurement

Ref. No.	*Quantity*	*Primary unit (symbol)*	*Non-SI alternative unit (symbol)*
1.	***Direction/Space/Time***		
1.1	altitude	m	ft
1.2	area	m^2	
1.3	distance (long)[a)]	km	NM
1.4	distance (short)	m	
1.5	elevation	m	ft
1.6	endurance	h and min	
1.7	height	m	ft
1.8	latitude	° ' "	
1.9	length	m	
1.10	longitude	° ' "	
1.11	plane angle (when required, decimal subdivisions of the degree shall be used)	°	
1.12	runway length	m	
1.13	runway visual range	m	
1.14	tank capacities (aircraft)[b)]	L	
1.15	time	s min h d week month year	
1.16	visibility[c)]	km	
1.17	volume	m^3	
1.18	wind direction (wind directions other than for a landing and take-off shall be expressed in degrees true; for landing and take- off wind directions shall be expressed in degrees magnetic)	°	

2. *Mass-related*

2.1	air density	kg/m^3	
2.2	area density	kg/m^2	
2.3	cargo capacity	kg	
2.4	cargo density	kg/m^3	
2.5	density (mass density)	kg/m^3	
2.6	fuel capacity (gravimetric)	kg	
2.7	gas density	kg/m^3	
2.8	gross mass or payload	kg t	
2.9	hoisting provisions	kg	
2.10	linear density	kg/m	
2.11	liquid density	kg/m^3	
2.12	mass	kg	
2.13	moment of inertia	$kg \cdot m^2$	
2.14	moment of momentum	$kg \cdot m^2/s$	
2.15	momentum	$kg \cdot m/s$	

3. *Force-related*

3.1	air pressure (general)	kPa	
3.2	altimeter setting	hPa	
3.3	atmospheric pressure	hPa	
3.4	bending moment	$kN \cdot m$	
3.5	force	N	
3.6	fuel supply pressure	kPa	
3.7	hydraulic pressure	kPa	
3.8	modulus of elasticity	MPa	
3.9	pressure	kPa	
3.10	stress	MPa	
3.11	surface tension	mN/m	
3.12	thrust	kN	
3.13	torque	$N \cdot m$	
3.14	vacuum	Pa	

4. *Mechanics*

4.1	airspeed[d)]	km/h	kt
4.2	angular acceleration	rad/s^2	
4.3	angular velocity	rad/s	
4.4	energy or work	J	
4.5	equivalent shaft power	kW	
4.6	frequency	Hz	
4.7	ground speed	km/h	kt
4.8	impact	J/m^2	
4.9	kinetic energy absorbed by brakes	MJ	
4.10	linear acceleration	m/s^2	
4.11	power	kW	
4.12	rate of trim	°/s	

4.13	shaft power	kW	
4.14	velocity	m/s	
4.15	vertical speed	m/s	ft/min
4.16	wind speed[e)]	m/s	kt

5. *Flow*

5.1	engine airflow	kg/s
5.2	engine waterflow	kg/h
5.3	fuel consumption (specific)	kg/(kW · h)
	piston engines	
	turbo-shaft engines	kg/(kW · h)
	jet engines	kg/(kN · h)
5.4	fuel flow	kg/h
5.5	fuel tank filling rate (gravimetric)	kg/min
5.6	gas flow	kg/s
5.7	liquid flow (gravimetric)	g/s
5.8	liquid flow (volumetric)	L/s
5.9	mass flow	kg/s
5.10	oil consumption	
	gas turbine	kg/h
	piston engines (specific)	g/(kW · h)
5.11	oil flow	g/s
5.12	pump capacity	L/min
5.13	ventilation airflow	m^3/min
5.14	viscosity (dynamic)	Pa · s
5.15	viscosity (kinematic)	m^2/s

6. *Thermodynamics*

6.1	coefficient of heat transfer	W/(m^2 · K)
6.2	heat flow per unit area	J/m^2
6.3	heat flow rate	W
6.4	humidity (absolute)	g/kg
6.5	coefficient of linear expansion	$°C^{-1}$
6.6	quantity of heat	J
6.7	temperature	°C

7. *Electricity and magnetism*

7.1	capacitance	F
7.2	conductance	S
7.3	conductivity	S/m
7.4	current density	A/m^2
7.5	electric current	A
7.6	electric field strength	C/m^2
7.7	electric potential	V
7.8	electromotive force	V
7.9	magnetic field strength	A/m
7.10	magnetic flux	Wb
7.11	magnetic flux density	T

7.12	power	W
7.13	quantity of electricity	C
7.14	resistance	Ω

8. *Light and related electromagnetic radiations*

8.1	illuminance	lx
8.2	luminance	cd/m^2
8.3	luminous exitance	lm/m^2
8.4	luminous flux	lm
8.5	luminous intensity	cd
8.6	quantity of light	lm · s
8.7	radiant energy	J
8.8	wavelength	m

9. *Acoustics*

9.1	frequency	Hz
9.2	mass density	kg/m^3
9.3	noise level	dB[e)]
9.4	period, periodic time	s
9.5	sound intensity	W/m^2
9.6	sound power	W
9.7	sound pressure	Pa
9.8	sound level	dB[f)]
9.9	static pressure (instantaneous)	Pa
9.10	velocity of sound	m/s
9.11	volume velocity (instantaneous)	m^3/s
9.12	wavelength	m

10. *Nuclear physics and ionizing radiation*

10.1	absorbed dose	Gy
10.2	absorbed dose rate	Gy/s
10.3	activity of radionuclides	Bq
10.4	dose equivalent	Sv
10.5	radiation exposure	C/kg
10.6	exposure rate	C/kg · s

a) As used in navigation, generally in excess of 4 000 m.
b) Such as aircraft fuel, hydraulic fluids, water, oil and high pressure oxygen vessels.
c) Visibility of less than 5 km may be given in m.
d) Airspeed is sometimes reported in flight operations in terms of the ratio MACH number.
e) A conversion of 1 kt = 0.5 m/s is used in ICAO Annexes for the representation of wind speed.
f) The decibel (dB) is a ratio which may be used as a unit for expressing sound pressure level and sound power level. When used, the reference level must be specified.

CHAPTER 4. TERMINATION OF USE OF NON-SI ALTERNATIVE UNITS

Introductory Note.- *The non-SI units listed in Table 3-3 have been retained temporarily for use as alternative units because of their widespread use and to avoid potential safety problems which could result from the lack of international coordination concerning the termination of their use. As termination dates are established by the Council, they will be reflected as Standards contained in this Chapter. It is expected that the establishment of such dates will be well in advance of actual termination. Any special procedures associated with specific unit termination will be circulated to all States separately from this Annex.*

4.1 The use in international civil aviation operations of the alternative non-SI units listed in Table 3-3 shall be terminated on the dates listed in Table 4-1.

Table 4-1. Termination dates for non-SI alternative units

Non-SI alternative unit	*Termination date*
Knot Nautical mile	not established[a)]
Foot	not established[b)]

a) No termination date has yet been established for use of nautical mile and knot.

b) No termination date has yet been established for use of the foot.

ATTACHMENT A. DEVELOPMENT OF THE INTERNATIONAL SYSTEM OF UNITS (SI)

1. Historical background

1.1 The name SI is derived from "Système International d'Unités". The system has evolved from units of length and mass (metre and kilogram) which were created by members of the Paris Academy of Sciences and adopted by the French National Assembly in 1795 as a practical measure to benefit industry and commerce. The original system became known as the metric system. Physicists realized the advantages of the system and it was soon adopted in scientific and technical circles.

1.2 International standardization began with an 1870 meeting of 15 States in Paris that led to the International Metric Convention in 1875 and the establishment of a permanent International Bureau of Weights and Measures. A General Conference on Weights and Measures (CGPM) was also constituted to handle all international matters concerning the metric system. In 1889 the first meeting of the CGPM legalized the old prototype of the metre and the kilogram as the international standard for unit of length and unit of mass, respectively. Other units were agreed in subsequent meetings and by its 10th Meeting in 1954, the CGPM had adopted a rationalized and coherent system of units based on the metre-kilogram-second-ampere (MKSA) system which had been developed earlier, plus the addition of the kelvin as the unit of temperature and the candela as the unit of luminous intensity. The 11th CGPM, held in 1960 and in which 36 States participated, adopted the name International System of Units (SI) and laid down rules for the prefixes, the derived and supplementary units and other matters, thus establishing comprehensive specifications for international units of measurement. The 12th CGPM in 1964 made some refinements in the system, and the 13th CGPM in 1967 redefined the second, renamed the unit of temperature as the kelvin (K) and revised the definition of the candela. The 14th CGPM in 1971 added a seventh base unit, the mole (mol) and approved the pascal (Pa) as a special name for the SI unit of pressure or stress, the newton (N) per square metre (m^2) and the siemens (S) as a special name for the unit of electrical conductance. In 1975 the CGPM adopted the becquerel (Bq) as the unit of the activity of radionuclides and the gray (Gy) as the unit for absorbed dose.

2. International Bureau of Weights and Measures

2.1 The Bureau International des Poids et Mesures (BIPM) was set up by the Metre Convention signed in Paris on 20 May 1875 by 17 States during the final session of the Diplomatic Conference of the Metre. This Convention was amended in 1921. BIPM has its headquarters near Paris and its upkeep is financed by the Member States of the Metre Convention. The task of BIPM is to ensure worldwide unification of physical measurements; it is responsible for:

- establishing the fundamental standards and scales for measurement of the principal physical quantities and maintaining the international prototypes;
- carrying out comparisons of national and international standards;
- ensuring the coordination of corresponding measuring techniques;
- carrying out and coordinating the determinations relating to the fundamental physical constants.

2.2 BIPM operates under the exclusive supervision of the International Committee of Weights and Measures (CIPM), which itself comes under the authority of the General Conference of Weights and Measures (CGPM). The International Committee consists of 18 members each belonging to a different State; it meets at least once every two years. The officers of this Committee issue an Annual Report on the administrative and financial position of BIPM to the Governments of the Member States of the Metre Convention.

2.3 The activities of BIPM, which in the beginning were limited to the measurements of length and mass and to metrological studies in relation to these quantities, have been extended to standards of measurement for electricity (1927), photometry (1937) and ionizing radiations (1960). To this end the original laboratories, built in 1876–78, were enlarged in 1929 and two new buildings were constructed in 1963–64 for the ionizing radiation laboratories. Some 30 physicists or technicians work in the laboratories of BIPM. They do metrological research, and also undertake measurement and certification of material standards of the above-mentioned quantities.

2.4 In view of the extension of the work entrusted to BIPM, CIPM has set up since 1927, under the name of Consultative Committees, bodies designed to provide it with information on matters which it refers to them for study and advice. These Consultative Committees, which may form temporary or permanent working groups to study special subjects, are responsible for coordinating the international work carried out in their respective fields and proposing recommendations concerning the amendment to be made to the definitions and values of units. In order to ensure worldwide uniformity in units of measurement, the International Committee accordingly acts directly or submits proposals for sanction by the General Conference.

2.5 The Consultative Committees have common regulations (*Procès-Verbaux CIPM*, 1963, 31, 97). Each Consultative Committee, the chairman of which is normally a member of CIPM, is composed of a delegate from each of the large metrology laboratories and specialized institutes, a list of which is drawn up by CIPM, as well as individual members also appointed by CIPM and one representative of BIPM. These Committees hold their meetings at irregular intervals; at present there are seven of them in existence as follows:

1. The Consultative Committee for Electricity (CCE), set up in 1927.

2. The Consultative Committee for Photometry and Radiometry (CCPR), which is the new name given in 1971 to the Consultative Committee for Photometry set up in 1933 (between 1930 and 1933 the preceding committee (CCE) dealt with matters concerning photometry).

3. The Consultative Committee for Thermometry (CCT), set up in 1937.

4. The Consultative Committee for the Definition of the Metre (CCDM), set up in 1952.

5. The Consultative Committee for the Definition of the Second (CCDS), set up in 1956.

6. The Consultative Committee for the Standards of Measurement of Ionizing Radiation (CCEMRI), set up in 1958. Since 1969 this Consultative Committee has consisted of four sections: Section I (measurement of X- and γ-rays); Section II (measurement of radionuclides); Section III (neutron measurements); Section IV (α-energy standards).

7. The Consultative Committee for Units (CCU), set up in 1964.

The proceedings of the General Conference, the International Committee, the Consultative Committees and the International Bureau are published under the auspices of the latter in the following series:

— *Comptes rendus des séances de la Conférence Générale des Poids et Mesures;*

— *Procès-Verbaux des séances du Comité International des Poids et Mesures;*

— *Sessions des Comités Consultatifs;*

— *Recueil de Travaux du Bureau International des Poids et Mesures* (this compilation brings together articles published in scientific and technical journals and books, as well as certain work published in the form of duplicated reports).

2.6 From time to time BIPM publishes a report on the development of the metric system throughout the world, entitled *Les récents progrès du Système Métrique.* The collection of the *Travaux et Mémoires du Bureau International des Poids et Mesures* (22 volumes published between 1881 and 1966) ceased in 1966 by a decision of the CIPM. Since 1965 the international journal *Metrologia*, edited under the auspices of CIPM, has published articles on the more important work on scientific metrology carried out throughout the world, on the improvement in measuring methods and standards, of units, etc., as well as reports concerning the activities, decisions and recommendations of the various bodies created under the Metre Convention.

3. International Organization for Standardization

The International Organization for Standardization (ISO) is a worldwide federation of national standards institutes which, although not a part of the BIPM, provides recommendations for the use of SI and certain other units. ISO Document 1000 and the ISO Recommendation R31 series of documents provide extensive detail on the application of the SI units. ICAO maintains liaison with ISO regarding the standardized application of SI units in aviation.

ATTACHMENT B. GUIDANCE ON THE APPLICATION OF THE SI

1. Introduction

1.1 The International System of Units is a complete, coherent system which includes three classes of units:

a) base units;

b) supplementary units; and

c) derived units.

1.2 The SI is based on seven units which are dimensionally independent and are listed in Table B-1.

1.3 The supplementary units of the SI are listed in Table B-2 and may be regarded either as base units or as derived units.

Table B-1. SI base units

Quantity	*Unit*	*Symbol*
amount of a substance	mole	mol
electric current	ampere	A
length	metre	m
luminous intensity	candela	cd
mass	kilogram	kg
thermodynamic temperature	kelvin	K
time	second	s

Table B-2. SI supplementary units

Quantity	*Unit*	*Symbol*
plane angle	radian	rad
solid angle	steradian	sr

1.4 Derived units of the SI are formed by combining base units, supplementary units and other derived units according to the algebraic relations linking the corresponding quantities. The symbols for derived units are obtained by means of the mathematical signs for multiplication, division and the use of exponents. Those derived SI units which have special names and symbols are listed in Table B-3.

Note.- The specific application of the derived units listed in Table B-3 and other units common to international civil aviation operations is given in Table 3-4.

Table B-3. SI derived units with special names

Quantity	*Unit*	*Symbol*	*Derivation*
absorbed dose (radiation)	gray	Gy	J/kg
activity of radionuclides	becquerel	Bq	l/s
Capacitance	farad	F	C/V
Conductance	siemens	S	A/V
dose equivalent (radiation)	sievert	Sv	J/kg
electric potential, potential difference, electromotive force	volt	V	W/A
electric resistance	ohm	Ω	V/A
energy, work, quantity of heat	joule	J	N · m
Force	newton	N	kg · m/s^2
frequency (of a periodic phenomenon)	hertz	Hz	l/s
Illuminance	lux	lx	lm/m^2
Inductance	henry	H	Wb/A
luminous flux	lumen	lm	cd · sr
magnetic flux	weber	Wb	V · s
magnetic flux density	tesla	T	Wb/m^2
power, radiant flux	watt	W	J/s
pressure, stress	pascal	Pa	N/m^2
quantity of electricity, electric charge	coulomb	C	A · s

1.5 The SI is a rationalized selection of units from the metric system which individually are not new. The great advantage of SI is that there is only one unit for each physical quantity - the metre for length, kilogram (instead of gram) for mass, second for time, etc. From these elemental or base units, units for all other mechanical quantities are derived. These derived units are defined by simple relationships such as velocity equals rate of change of distance, acceleration equals rate of change of velocity, force is the product of mass and acceleration, work or energy is the product of force and distance, power is work done per unit time, etc. Some of these units have only generic names such as metre per second for velocity; others have special names such as newton (N) for force, joule (J) for work or energy, watt (W) for power. The SI units for force, energy and power are the same regardless of whether the process is mechanical, electrical, chemical or nuclear. A force of newton applied for a distance of 1 metre can produce 1 joule of heat, which is identical with what 1 watt of electric power can produce in 1 second.

1.6 Corresponding to the advantages of SI, which result from the use of a unique unit for each physical quantity, are the advantages which result from the use of a unique and well-defined set of symbols and abbreviations. Such symbols and abbreviations eliminate the confusion that can arise from current practices in different disciplines such as the use of “b” for both the bar (a unit of pressure) and barn (a unit of area).

1.7 Another advantage of SI is its retention of the decimal relation between multiples and sub-multiples of the base units for each physical quantity. Prefixes are established for designating multiple and sub-multiple units from “exa” (10^{18}) down to “atto” (10^{-18}) for convenience in writing and speaking.

1.8 Another major advantage of SI is its coherence. Units might be chosen arbitrarily, but making an independent choice of a unit for each category of mutually comparable quantities would lead in general to the appearance of several additional numerical factors in the equations between the numerical values. It is possible, however, and in practice more convenient, to choose a system of units in such a way that the equations between numerical values, including the numerical factors, have exactly the same form as the corresponding equations between the quantities. A unit system defined in this way is called coherent with respect to the system of quantities and equations in question. Equations between units of a coherent unit system contain as numerical factors only the number 1. In a coherent system the product or quotient of any two unit quantities is the unit of the resulting quantity. For example, in any coherent system, unit area results when unit length is multiplied by unit length, unit velocity when unit length is divided by unit time, and unit force when unit mass is multiplied by unit acceleration.

Note.- *Figure B-1 illustrates the relationship of the units of the SI.*

2. Mass, force and weight

2.1 The principal departure of SI from the gravimetric system of metric engineering units is the use of explicitly distinct units from mass and force. In SI, the name kilogram is restricted to the unit of mass, and the kilogram-force (from which the suffix force was in practice often erroneously dropped) is not to be used. In its place the SI unit of force, the newton, is used. Likewise, the newton rather than the kilogram-force is used to form derived units which include force, for example, pressure or stress (N/m^2 = Pa), energy (N m = J), and power (N·m/s = W).

2.2 Considerable confusion exists in the use of the term weight as a quantity to mean either force or mass. In common use, the term weight nearly always means mass; thus, when one speaks of a person's weight, the quantity referred to is mass. In science and technology, the term weight of a body has usually meant the force that, if applied to the body, would give it an acceleration equal to the local acceleration of free fall. The adjective "local" in the phrase "local acceleration of free fall" has usually meant a location on the surface of the earth; in this context the "local acceleration of free fall" has the symbol g (sometimes referred to as "acceleration of gravity") with observed values of g differing by over 0.5 per cent at various points on the earth's surface and decreasing as distance from the earth is increased. Thus, because weight is a force = mass × acceleration due to gravity, a person's weight is conditional on the person's location, but mass is not. A person with a mass of 70kg might experience a force (weight) on earth of 686 newtons (≈155 lbf) and a force (weight) of only 113 newtons (≈22 lbf) on the moon. Because of the dual use of the term weight as a quantity, the term weight should be avoided in technical practice except under circumstances in which its meaning is completely clear. When the term is used, it is important to know whether mass or force is intended and to use SI units properly by using kilograms for mass or newtons for force.

2.3 Gravity is involved in determining mass with a balance or scale. When a standard mass is used to balance the measured mass, the direct effect of gravity on the two masses is cancelled, but the indirect effect through the buoyancy of air or other fluid is generally not cancelled. In using a spring scale, mass is measured indirectly, since the instrument responds to the force of gravity. Such scales may be calibrated in mass units if the variation in acceleration of gravity and buoyancy corrections are not significant in their

use.

3. Energy and torque

3.1 The vector product of force and moment arm is widely designated by the unit newton metre. This unit for bending moment or torque results in confusion with the unit for energy, which is also newton metre. If torque is expressed as newton metre per radian, the relationship to energy is clarified, since the product of torque and angular rotation is energy:

$(N \cdot m/rad) \cdot rad = N \cdot m$

3.2 If vectors were shown, the distinction between energy and torque would be obvious, since the orientation of force and length is different in the two cases. It is important to recognize this difference in using torque and energy, and the joule should never be used for torque.

4. SI prefixes

4.1 Selection of prefixes

4.1.1 In general the SI prefixes should be used to indicate orders of magnitude, thus eliminating non-significant digits and leading zeros in decimal fractions and providing a convenient alternative to the powers-of-ten notation preferred in computation. For example:

12300 mm becomes 12.3 m

12.3×10^3 m becomes 12.3 km

0.001 23 µA becomes 1.23 nA

4.1.2 When expressing a quantity by a numerical value and a unit, prefixes should preferably be chosen so that the numerical value lies between 0.1 and 1000. To minimize variety, it is recommended that prefixes representing powers of 1000 be used. However, in the following cases, deviation from the above may be indicated:

a) in expressing area and volume, the prefixes hecto, deca, deci and centi may be required: for example, square hectometre, cubic centimetre;

b) in tables of values of the same quantity, or in a discussion of such values within a given context, it is generally preferable to use the same unit multiple throughout; and

c) for certain quantities in particular applications, one particular multiple is customarily used. For example, the hectopascal is used for altimeter settings and the millimetre is used for linear dimensions in mechanical engineering drawings even when the values lie outside the range 0.1 to 1000.

4.2 Prefixes in compound units[1]

It is recommended that only one prefix be used in forming a multiple of a compound unit. Normally the prefix should be attached to a unit in the numerator. One exception to this occurs when the kilogram is one of the units. For example:

V/m, *not* mV/mm; MJ/kg, *not* kJ/g

4.3 Compound prefixes

Compound prefixes, formed by the juxtaposition of two or more SI prefixes, are not to be used. For example:

1 nm *not* 1mμm; 1 pF *not* 1μμF

If values are required outside the range covered by the prefixes, they should be expressed using powers of ten applied to the base unit.

1. A compound unit is a derived unit expressed in terms of two or more units, that is, not expressed with a single special name

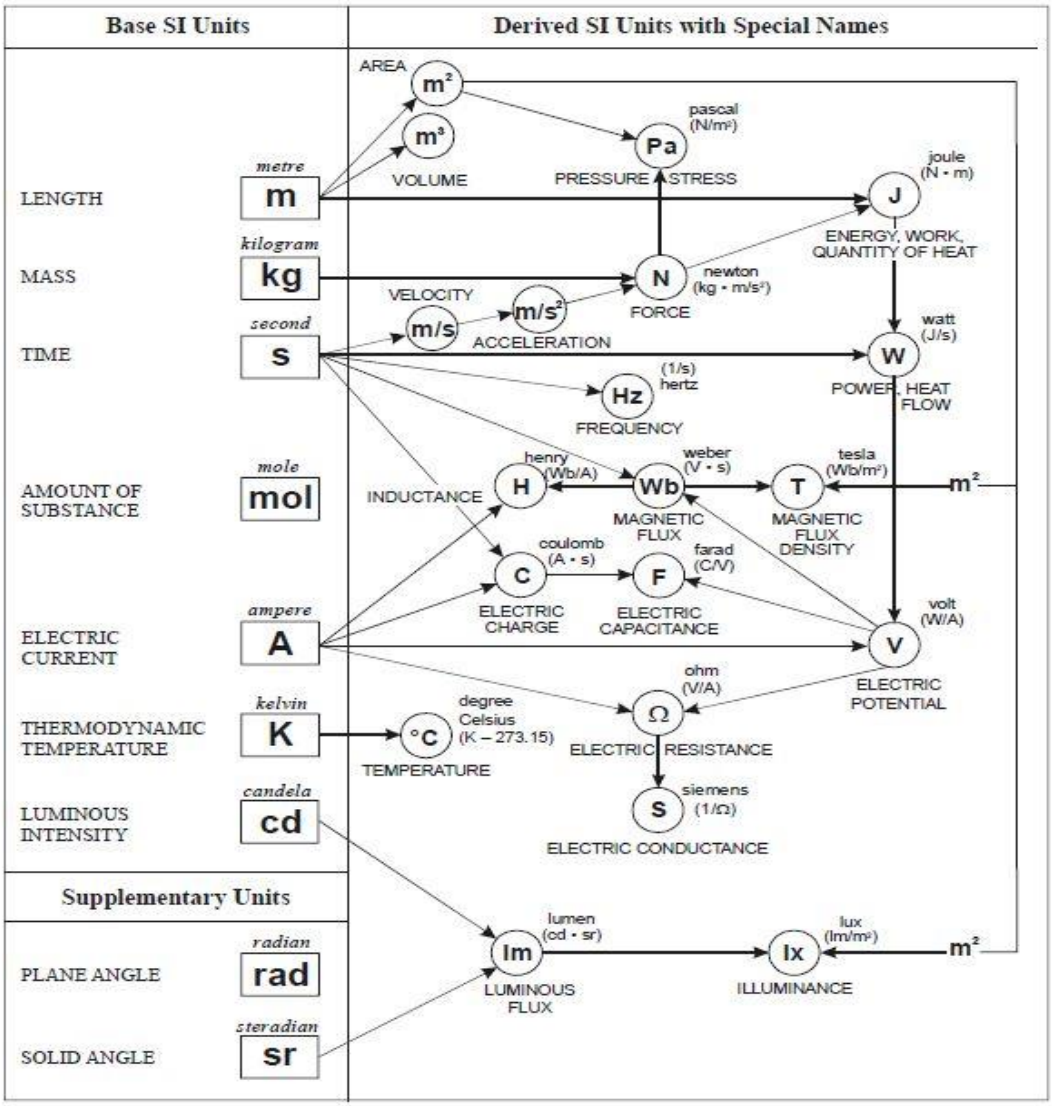


Figure B-1

4.4 Powers of units

An exponent attached to a symbol containing a prefix indicates that the multiple or sub-multiple of the unit (the unit with its prefix) is raised to the power expressed by the exponent. For example:

$1\ cm^3 = (10^{-2}\ m)^3 = 10^{-6}\ m^3$ $1\ ns^{-1} = (10^{-9}\ s)^{-1} = 10^9\ s^{-1}$

$1\ mm^2/s = (10^{-3}\ m)^2/s = 10^{-6}\ m^2/s$

5. Style and usage

5.1 Rules for writing unit symbols

5.1.1 Unit symbols should be printed in Roman (upright) type regardless of the type style used in the surrounding text.

5.1.2 Unit symbols are unaltered in the plural.

5.1.3 Unit symbols are not followed by a period except when used at the end of a sentence.

5.1.4 Letter unit symbols are written in lower case (cd) unless the unit name has been derived from a proper name, in which case the first letter of the symbol is capitalized (W, Pa). Prefix and unit symbols retain their prescribed form regardless of the surrounding typography.

5.1.5 In the complete expression for a quantity, a space should be left between the numerical value and the unit symbol. For example, write 35 mm not 35mm, and 2.37 lm, not 2.37lm. When the quantity is used in an adjectival sense, a hyphen is often used, for example, 35-mm film.

Exception: No space is left between the numerical value and the symbols for degree, minute and second of plane angle, and degree Celsius.

5.1.6 No space is used between the prefix and unit symbols.

5.1.7 Symbols, not abbreviations, should be used for units. For example, use “A”, not “amp”, for ampere.

5.2 Rules for writing unit names

5.2.1 Spelled-out unit names are treated as common nouns in English. Thus, the first letter of a unit name is not capitalized except at the beginning of a sentence or in capitalized material such as a title, even though the unit name may be derived from a proper name and therefore be represented as a symbol by a capital letter (see 5.1.4). For example, normally write “newton” not “Newton” even though the symbol is N.

5.2.2 Plurals are used when required by the rules of grammar and are normally formed regularly, for example, henries for the plural of henry. The following irregular plurals are recommended:

Singular *Plural*

lux	lux
hertz	hertz
siemens	siemens

5.2.3 No space or hyphen is used between the prefix and the unit name.

5.3 Units formed by multiplication and division

5.3.1 With unit names:

Product, use a space (preferred) or hyphen:

newton metre *or* newton-metre.

In the case of the watt hour the space may be omitted, thus:

watthour.

Quotient, use the word per and not a solidus:

metre per second *not* metre/second.

Powers, use the modifier squared or cubed placed after the unit name:

metre per second squared.

I the case of area or volume, a modifier may be placed before the unit name:

square millimetre, cubic metre.

This exception also applies to derived units using area or volume:

watt per square metre.

Note.- *To avoid ambiguity in complicated expressions, symbols are preferred to words.*

5.3.2 *With unit symbols:*

Product may be indicated in either of the following ways:

Nm *or* N · m for newton metre.

Note.- *When using for a prefix a symbol which coincides with the symbol for the unit, special care should be taken to avoid confusion. The unit newton metre for torque should be written, for example,* Nm *or* N · m *to avoid confusion with* mN, *the millinewton.*

An exception to this practice is made for computer printouts, automatic typewriter work, etc., where the dot half high is not possible, and a dot on the line may be used.

Quotient, use one of the following forms:

m/s *or* $m \cdot s^{-1}$ *or* $\frac{m}{s}$.

In no case should more than one solidus be used in the same expression unless parentheses are inserted to avoid ambiguity. For example, write:

J/(mol · K) *or* $J \cdot mol^{-1} \cdot K^{-1}$ *or* (J/mol)/K

but *not* J/mol/K.

5.3.3 Symbols and unit names should not be mixed in the same expression. Write:

joules per kilogram *or* J/kg *or* $J \cdot kg^{-1}$

but *not* joules/kilogram *or* joules/kg *or* joules $\cdot kg^{-1}$.

5.4 Numbers

5.4.1 The preferred decimal marker is a point on the line (period); however, the comma is also acceptable. When writing numbers less than one, a zero should be written before the decimal marker.

5.4.2 The comma is not to be used to separate digits. Instead, digits should be separated into groups of three, counting from the decimal point towards the left and the right, and using a small space to separate the groups. For example:

73655 7281 2.567321 0.13347

The space between groups should be approximately the width of the letter "i" and the width of the space should be constant even if variable-width spacing is used between the words.

5.4.3 The sign for multiplication of numbers is a cross (×) or a dot half high. However, if the dot half high is used as the multiplication sign, a point on the line must not be used as a decimal marker in the same expression.

5.4.4 Attachment of letters to a unit symbol as a means of giving information about the nature of the quantity under consideration is incorrect. Thus MWe for "megawatts electrical (power)", Vac for "volts ac" and kJt for "kilojoules thermal (energy)" are not acceptable. For this reason, no attempt should be made to construct SI equivalents of the abbreviations "psia" and "psig", so often used to distinguish between absolute and gauge pressure. If the context leaves any doubt as to which is meant, the word pressure must be qualified appropriately. For example:

"… at a gauge pressure of 13 kPa".

or

"… at an absolute pressure of 13 kPa".

ATTACHMENT C. CONVERSION FACTORS

1. General

1.1 The list of conversion factors which is contained in this Attachment is provided to express the definitions of miscellaneous units of measure as numerical multiples of SI units.

1.2 The conversion factors are presented for ready adaptation to computer readout and electronic data transmission. The factors are written as a number greater than 1 and less than 10 with six or less decimal places. This number is followed by the letter E (for exponent), a plus or minus symbol, and two digits which indicate the power of 10 by which the number must be multiplied to obtain the correct value. For example:

3.523 907 E – 02 is $3.523\,907 \times 10^{-2}$ *or* 0.035 239 07

Similarly,

3.386 389 E + 03 is $3.386\,389 \times 10^{3}$ *or* 3 386.389

1.3 An asterisk (*) after the sixth decimal place indicates that the conversion factor is exact and that all subsequent digits are zero. Where less than six decimal places are shown, more precision is not warranted.

1.4 Further examples of use of the tables:

To convert from	*to*	*Multiply by*	
pound-force per square foot	Pa	4.788	026 E + 01
Inch	m	2.540	000*E – 02

thus:

1 lbf/ft^2 = 47.880 26 Pa

1 inch = 0.025 4 m (exactly)

2. Factors not listed

2.1 Conversion factors for compound units which are not listed herein can easily be developed from numbers given in the list by the substitution of converted units, as follows.
Example: To find conversion factor of lb · ft/s to kg · m/s:

first convert
1 lb to 0.453 592 4 kg
1 ft to 0.304 8 m

then substitute:
(0.453 592 4 kg) × (0.304 8 m)/s = 0.138 255 kg · m/s

Thus the factor is 1.382 55 E – 01.

Table C-1. Conversion factors to SI units

(Symbols of SI units given in parentheses)

To convert from	*To*	*Multiply by*	
Abampere	ampere (A)	1.000000	∗E + 01
Abcoulomb	coulomb (C)	1.000000	*E + 01
Abfarad	farad (F)	1.000000	*E + 09
Abhenry	henry (H)	1.000000	*E – 09
Abmho	siemens (S)	1.000000	*E + 09
Abohm	ohm (Ω)	1.000000	*E – 09
Abvolt	volt (V)	1.000000	*E – 08
acre (U.S. survey)	square metre (m^2)	4.046873	E + 03
ampere hour	coulomb (C)	3.600000	*E + 03
Are	square metre (m^2)	1.000000	*E + 02
atmosphere (standard)	pascal (Pa)	1.013250	*E + 05
atmosphere (technical = 1 kgf/cm^2)	pascal (Pa)	9.806650	*E + 04
Bar	pascal (Pa)	1.000000	*E + 05
barrel (for petroleum, 42 U.S. liquid gal)	cubic metre (m^3)	1.589873	*E – 01
British thermal unit (International Table)	joule (J)	1.055056	E + 03
British thermal unit (mean)	joule (J)	1.05587	E + 03
British thermal unit (thermochemical)	joule (J)	1.054350	E + 03
British thermal unit (39°F)	joule (J)	1.05967	E + 03
British thermal unit (59°F)	joule (J)	1.05480	E + 03
British thermal unit (60°F)	joule (J)	1.05468	E + 03
Btu (International Table) · ft/h · ft^2 · °F (k, thermal conductivity)	watt per metre kelvin (W/m · K)	1.730735	E + 00
Btu (thermochemical) · ft/h · ft^2 · °F (k, thermal conductivity)	watt per metre kelvin (W/m · K)	1.729577	E + 00
Btu (International Table) · in/h · ft^2 · °F (k, thermal conductivity)	watt per metre kelvin (W/m · K)	1.442279	E – 01
Btu (thermochemical) · in/h · ft^2 · °F (k, thermal conductivity)	watt per metre kelvin (W/m · K)	1.441314	E – 01
Btu (International Table) · in/s · ft^2 · °F (k, thermal conductivity)	watt per metre kelvin (W/m · K)	5.192204	E + 02
Btu (thermochemical) · in/s · ft^2 · °F (k, thermal conductivity)	watt per metre kelvin (W/m · K)	5.188732	E + 02
Btu (International Table)/h	watt (W)	2.930 711	E – 01
Btu (thermochemical)/h	watt (W)	2.928 751	E – 01
Btu (thermochemical)/min	watt (W)	1.757250	E + 01
Btu (thermochemical)/s	watt (W)	1.054350	E + 03

Btu (International Table)/ft^2	joule per square metre (J/m^2)	1.135653	E + 04
Btu (thermochemical)/ft^2	joule per square metre (J/m^2)	1.134893	E + 04
Btu (thermochemical)/ft^2 · h	watt per square metre (W/m^2)	3.152481	E + 00
Btu (thermochemical)/ft^2 · min	watt per square metre (W/m^2)	1.891489	E + 02
Btu (thermochemical)/ft^2 · s	watt per square metre (W/m^2)	1.134893	E + 04
Btu (thermochemical)/in^2 · s	watt per square metre (W/m^2)	1.634246	E + 06

* An asterisk (*) after the sixth decimal place indicates that the conversion factor is exact and that all subsequent digits are zero. Where less than six decimal places are shown, more precision is not warranted.

To convert from	*To*	*Multiply by*	
Btu (International Table)/h · ft^2 · °F (C, thermal conductance)	watt per square metre kelvin (W/m^2 · K)	5.678263	E + 00
Btu (thermochemical)/h · ft^2 · °F (C, thermal conductance)	watt per square metre kelvin (W/m^2 · K)	5.674466	E + 00
Btu (International Table)/s · ft^2 · °F	watt per square metre kelvin (W/m^2 · K)	2.044175	E + 04
Btu (thermochemical)/s · ft^2 · °F	watt per square metre kelvin (W/m^2 · K)	2.042808	E + 04
Btu (International Table)/lb	joule per kilogram (J/kg)	2.326000	*E + 03
Btu (thermochemical)/lb	joule per kilogram (J/kg)	2.324444	E + 03
Btu (International Table)/lb · °F (c, heat capacity)	joule per kilogram kelvin (J/kg · K)	4.186800	*E + 03
Btu (thermochemical)/lb · °F (c, heat capacity)	joule per kilogram kelvin (J/kg · K)	4.184000	E + 03
calibre (inch)	metre (m)	2.540000	*E – 02
calorie (International Table)	joule (J)	4.186800	*E + 00
calorie (mean)	joule (J)	4.19002	E + 00
calorie (thermochemical)	joule (J)	4.184000	*E + 00
calorie (15°C)	joule (J)	4.18580	E + 00
calorie (20°C)	joule (J)	4.18190	E + 00
calorie (kilogram, International Table)	joule (J)	4.186800	*E + 03
calorie (kilogram, mean)	joule (J)	4.19002	E + 03
calorie (kilogram, thermochemical)	joule (J)	4.184000	*E + 03
cal (thermochemical)/cm^2	joule per square metre (J/m^2)	4.184000	*E + 04
cal (International Table)/g	joule per kilogram (J/kg)	4.186800	*E + 03
cal (thermochemical)/g	joule per kilogram (J/kg)	4.184000	*E + 03
cal (International Table)/g · °C	joule per kilogram kelvin (J/kg · K)	4.186800	*E + 03
cal (thermochemical)/g · °C	joule per kilogram kelvin (J/kg · K)	4.184000	*E + 03
cal (thermochemical)/min	watt (W)	6.973333	E – 02
cal (thermochemical)/s	watt (W)	4.184000	*E + 00
cal (thermochemical)/cm^2 · min	watt per square metre (W/m^2)	6.97333	E + 02
cal (thermochemical)/cm^2 · s	watt per square metre (W/m^2)	4.184000	*E + 04
cal (thermochemical)/cm · s · °C	watt per metre kelvin (W/m · K)	4.184000	*E + 02
centimetre of mercury (0°C)	pascal (Pa)	1.33322	E + 03
centimetre of water (4°C)	pascal (Pa)	9.80638	E + 01
centipoise	pascal second (Pa · s)	1.000000	*E – 03
centistokes	metre squared per second (m^2/s)	1.000000	*E – 06

circular mil	square metre (m^2)	5.067075	E – 10
clo	kelvin metre squared per watt (K · m^2/W)	2.003712	E – 01
cup	cubic metre (m^3)	2.365882	E – 04
curie	becquerel (Bq)	3.700000	*E + 10
day (mean solar)	second (s)	8.640000	E + 04
day (sidereal)	second (s)	8.616409	E + 04
degree (angle)	radian (rad)	1.745329	E – 02
°F · h · ft^2/Btu (International Table) (R, thermal resistance)	kelvin metre squared per watt (K · m^2/W)	1.761102	E – 01
°F · h · ft^2/Btu (thermochemical) (R, thermal resistance)	kelvin metre squared per watt (K · m^2/W)	1.762280	E – 01
dyne	newton (N)	1.000000	*E – 05
dyne · cm	newton metre (N · m)	1.000000	*E – 07
dyne/cm^2	pascal (Pa)	1.000000	*E – 01

To convert from	*To*	*Multiply by*	
electronvolt	joule (J)	1.60219	E – 19
EMU of capacitance	farad (F)	1.000000	*E + 09
EMU of current	ampere (A)	1.000000	*E + 01
EMU of electric potential	volt (V)	1.000000	*E – 08
EMU of inductance	henry (H)	1.000000	*E – 09
EMU of resistance	ohm (Ω)	1.000000	*E – 09
erg	joule (J)	1.000000	*E – 07
erg/cm^2 · s	watt per square metre (W/m^2)	1.000000	*E – 03
erg/s	watt (W)	1.000000	*E – 07
ESU of capacitance	farad (F)	1.112650	E – 12
ESU of current	ampere (A)	3.3356	E – 10
ESU of electric potential	volt (V)	2.9979	E + 02
ESU of inductance	henry (H)	8.987554	E + 11
ESU of resistance	ohm (Ω)	8.987554	E + 11
faraday (based on carbon-12)	coulomb (C)	9.64870	E + 04
faraday (chemical)	coulomb (C)	9.64957	E + 04
faraday (physical)	coulomb (C)	9.65219	E + 04
fathom	metre (m)	1.8288	E + 00
fermi (femtometre)	metre (m)	1.000000	*E – 15
fluid ounce (U.S.)	cubic metre (m^3)	2.957353	E – 05
foot	metre (m)	3.048000	*E – 01
foot (U.S. survey)	metre (m)	3.048006	E – 01
foot of water (39.2°F)	pascal (Pa)	2.98898	E + 03
ft^2	square metre (m^2)	9.290304	*E – 02
ft^2/h (thermal diffusivity)	metre squared per second (m^2/s)	2.580640	*E – 05
ft^2/s	metre squared per second (m^2/s)	9.290304	*E – 02
ft^3 (volume; section modulus)	cubic metre (m^3)	2.831685	E – 02
ft^3/min	cubic metre per second (m^3/s)	4.719474	E – 04
ft^3/s	cubic metre per second (m^3/s)	2.831685	E – 02
ft^4 (moment of section)	metre to the fourth power (m^4)	8.630975	E – 03
ft · lbf	joule (J)	1.355818	E + 00

ft · lbf/h	watt (W)	3.766161	E – 04
ft · lbf/min	watt (W)	2.259697	E – 02
ft · lbf/s	watt (W)	1.355818	E + 00
ft · poundal	joule (J)	4.214011	E – 02
free fall, standard (g)	metre per second squared (m/s^2)	9.806650	*E + 00
ft/h	metre per second (m/s)	8.466667	E – 05
ft/min	metre per second (m/s)	5.080000	*E – 03
ft/s	metre per second (m/s)	3.048000	*E – 01
ft/s^2	metre per second squared (m/s^2)	3.048000	*E – 01
footcandle	lux (lx)	1.076391	E + 01
footlambert	candela per square metre (cd/m^2)	3.426259	E + 00
gal	metre per second squared (m/s^2)	1.000000	*E – 02
gallon (Canadian liquid)	cubic metre (m^3)	4.546090	E – 03
gallon (U.K. liquid)	cubic metre (m^3)	4.546092	E – 03
gallon (U.S. dry)	cubic metre (m^3)	4.404884	E – 03
gallon (U.S. liquid)	cubic metre (m^3)	3.785412	E – 03
gal (U.S. liquid)/day	cubic metre per second (m^3/s)	4.381264	E – 08

To convert from	*to*	*Multiply by*	
gal (U.S. liquid)/min	cubic metre per second (m^3/s)	6.309020	E – 05
gal (U.S. liquid)/hp · h (SFC, specific fuel consumption)	cubic metre per joule (m^3/J)	1.410089	E – 09
gamma	tesla (T)	1.000000	*E – 09
gauss	tesla (T)	1.000000	*E – 04
gilbert	ampere (A)	7.957747	E – 01
grad	degree (angular)	9.000000	*E – 01
grad	radian (rad)	1.570796	E – 02
gram	kilogram (kg)	1.000000	*E – 03
g/cm^3	kilogram per cubic metre (kg/m^3)	1.000000	*E + 03
gram-force/cm^2	pascal (Pa)	9.806650	*E + 01
hectare	square metre (m^2)	1.000000	*E + 04
horsepower (550 ft · lbf/s)	watt (W)	7.456999	E + 02
horsepower (electric)	watt (W)	7.460000	*E + 02
horsepower (metric)	watt (W)	7.35499	E + 02
horsepower (water)	watt (W)	7.46043	E + 02
horsepower (U.K.)	watt (W)	7.4570	E + 02
hour (mean solar)	second (s)	3.600000	E + 03
hour (sidereal)	second (s)	3.590170	E + 03
hundredweight (long)	kilogram (kg)	5.080235	E + 01
hundredweight (short)	kilogram (kg)	4.535924	E + 01
inch	metre (m)	2.540000	*E – 02
inch of mercury (32°F)	pascal (Pa)	3.38638	E + 03
inch of mercury (60°F)	pascal (Pa)	3.37685	E + 03
inch of water (39.2°F)	pascal (Pa)	2.49082	E + 02
inch of water (60°F)	pascal (Pa)	2.4884	E + 02
in^2	square metre (m^2)	6.451600	*E – 04
in^3 (volume; section modulus)	cubic metre (m^3)	1.638706	E – 05

in^3/min	cubic metre per second (m^3/s)	2.731177	E – 07
in^4 (moment of section)	metre to the fourth power (m^4)	4.162314	E – 07
in/s	metre per second (m/s)	2.540000	*E – 02
in/s^2	metre per second squared (m/s^2)	2.540000	*E – 02
kilocalorie (International Table)	joule (J)	4.186800	*E + 03
kilocalorie (mean)	joule (J)	4.19002	E + 03
kilocalorie (thermochemical)	joule (J)	4.184000	*E + 03
kilocalorie (thermochemical)/min	watt (W)	6.973333	E + 01
kilocalorie (thermochemical)/s	watt (W)	4.184000	*E + 03
kilogram-force (kgf)	newton (N)	9.806650	*E + 00
kgf · m	newton metre (N · m)	9.806650	*E + 00
kgf · s^2/m (mass)	kilogram (kg)	9.806650	*E + 00
kgf/cm^2	pascal (Pa)	9.806650	*E + 04
kgf/m^2	pascal (Pa)	9.806650	*E + 00
kgf/mm^2	pascal (Pa)	9.806650	*E + 06
km/h	metre per second (m/s)	2.777778	E – 01
kilopond	newton (N)	9.806650	*E + 00
kW · h	joule (J)	3.600000	*E + 06
kip (1 000 lbf)	newton (N)	4.448222	E + 03

To convert from	*to*	*Multiply by*	
kip/in^2 (ksi)	pascal (Pa)	6.894757	E + 06
knot (international)	metre per second (m/s)	5.144444	E – 01
lambert	candela per square metre (cd/m^2)	1/π	*E + 04
lambert	candela per square metre (cd/m^2)	3.183099	E + 03
langley	joule per square metre (J/m^2)	4.184000	*E + 04
lb · ft^2 (moment of inertia)	kilogram metre squared (kg · m^2)	4.214011	E – 02
lb · in^2 (moment of inertia)	kilogram metre squared (kg · m^2)	2.926397	E – 04
lb/ft · h	pascal second (Pa · s)	4.133789	E – 04
lb/ft · s	pascal second (Pa · s)	1.488164	E + 00
lb/ft^2	kilogram per square metre (kg/m^2)	4.882428	E + 00
lb/ft^3	kilogram per cubic metre (kg/m^3)	1.601846	E + 01
lb/gal (U.K. liquid)	kilogram per cubic metre (kg/m^3)	9.977633	E + 01
lb/gal (U.S. liquid)	kilogram per cubic metre (kg/m^3)	1.198264	E + 02
lb/h	kilogram per second (kg/s)	1.259979	E – 04
lb/hp · h (SFC, specific fuel consumption)	kilogram per joule (kg/J)	1.689659	E – 07
lb/in^3	kilogram per cubic metre (kg/m^3)	2.767990	E + 04
lb/min	kilogram per second (kg/s)	7.559873	E – 03
lb/s	kilogram per second (kg/s)	4.535924	E – 01
lb/yd^3	kilogram per cubic metre (kg/m^3)	5.932764	E – 01
lbf · ft	newton metre (N · m)	1.355818	E + 00
lbf · ft/in	newton metre per metre (N · m/m)	5.337866	E + 01
lbf · in	newton metre (N · m)	1.129848	E – 01
lbf · in/in	newton metre per metre (N · m/m)	4.448222	E + 00

lbf · s/ft^2	pascal second (Pa · s)	4.788026 1.459	E + 01
lbf/ft	newton per metre (N/m)	390	E + 01
lbf/ft^2	pascal (Pa)	4.788026	E + 01
lbf/in	newton per metre (N/m)	1.751268	E + 02
lbf/in^2 (psi)	pascal (Pa)	6.894757	E + 03
lbf/lb (thrust/weight (mass) ratio)	newton per kilogram (N/kg)	9.806650	E + 00
light year	metre (m)	9.46055	E + 15
litre	cubic metre (m^3)	1.000000	*E – 03
maxwell	weber (Wb)	1.000000	*E – 08
mho	siemens (S)	1.000000	*E + 00
microinch	metre (m)	2.540000	*E – 08
micron	metre (m)	1.000000	*E – 06
mil	metre (m)	2.540000	*E – 05
mile (international)	metre (m)	1.609344	*E + 03
mile (statute)	metre (m)	1.6093	E + 03
mile (U.S. survey)	metre (m)	1.609347	E + 03
mile (international nautical)	metre (m)	1.852000	*E + 03
mile (U.K. nautical)	metre (m)	1.853184	*E + 03
mile (U.S. nautical)	metre (m)	1.852000	*E + 03
mi^2 (international)	square metre (m^2)	2.589988	E + 06
mi^2 (U.S. survey)	square metre (m^2)	2.589998	E + 06
mi/h (international)	metre per second (m/s)	4.470400	*E – 01
mi/h (international)	kilometre per hour (km/h)	1.609344	*E + 00
mi/min (international)	metre per second (m/s)	2.682240	*E + 01

To convert from	*to*	*Multiply by*	
mi/s (international)	metre per second (m/s)	1.609344	*E + 03
Millibar	pascal (Pa)	1.000000	*E + 02
millimetre of mercury (0°C)	pascal (Pa)	1.33322	E + 02
minute (angle)	radian (rad)	2.908882	E – 04
minute (mean solar)	second (s)	6.000000	E + 01
minute (sidereal)	second (s)	5.983617	E + 01
month (mean calendar)	second(s)	2.628000	E + 06
Oersted	ampere per metre (A/m)	7.957747	E + 01
ohm centimeter	ohm metre (Ω · m)		*E – 02
ohm circular-mil per ft	ohm millimetre squared per metre (Ω · mm^2/m)	1.662426	E – 03
ounce (avoirdupois)	kilogram (kg)	2.834952	E – 02
ounce (troy or apothecary)	kilogram (kg)	3.110348	E – 02
ounce (U.K. fluid)	cubic metre (m^3)	2.841307	E – 05
ounce (U.S. fluid)	cubic metre (m^3)	2.95735	E – 05
ounce-force	newton (N)	2.780139	E – 01
ozf · in	newton metre (N · m)	7.061552	E – 03
oz (avoirdupois)/gal (U.K. liquid)	kilogram per cubic metre (kg/m^3)	6.236021	E + 00
oz (avoirdupois)/gal (U.S. liquid)	kilogram per cubic metre (kg/m^3)	7.489152	E + 00
oz (avoirdupois)/in^3	kilogram per cubic metre (kg/m^3)	1.729994	E + 03

oz (avoirdupois)/ft^2	kilogram per square metre (kg/m^2)	3.051517	E – 01
oz (avoirdupois)/yd^2	kilogram per square metre (kg/m^2)	3.390575	E – 02
Parsec	metre (m)	3.085678	E + 16
Pennyweight	kilogram (kg)	1.555174	E – 03
perm (0°C)	kilogram per pascal second metre squared (kg/Pa · s · m^2)	5.72135	E – 11
perm (23°C)	kilogram per pascal second metre squared (kg/Pa · s · m^2)	5.74525	E – 11
perm · in (0°C)	kilogram per pascal second metre (kg/Pa · s · m)	1.45322	E – 12
perm · in (23°C)	kilogram per pascal second metre (kg/Pa · s · m)	1.45929	E – 12
Phot	lumen per square metre (lm/m^2)	1.000000	*E + 04
pint (U.S. dry)	cubic metre (m^3)	5.506105	E – 04
pint (U.S. liquid)	cubic metre (m^3)	4.731765	E – 04
poise (absolute viscosity)	pascal second (Pa · s)	1.000000	*E – 01
pound (lb avoirdupois)	kilogram (kg)	4.535 924	E – 01
pound (troy or apothecary)	kilogram (kg)	3.732417	E – 01
Poundal	newton (N)	1.382550	E – 01
poundal/ft^2	pascal (Pa)	1.488164	E + 00
poundal · s/ft^2	pascal second (Pa · s)	1.488164	E + 00
pound-force (lbf)	newton (N)	4.448222	E + 00
quart (U.S. dry)	cubic metre (m^3)	1.101221	E – 03
quart (U.S. liquid)	cubic metre (m^3)	9.463529	E – 04
rad (radiation dose absorbed)	gray (Gy)	1.000000	*E – 02
Rem	sievert (Sv)	1.000000	*E – 02

To convert from	*to*	*Multiply by*	
rhe	1 per pascal second (1/Pa · s)	1.000000	*E + 01
roentgen	coulomb per kilogram (C/kg)	2.58	E – 04
second (angle)	radian (rad)	4.848137	E – 06
second (sidereal)	second (s)	9.972696	E – 01
slug	kilogram (kg)	1.459390	E + 01
slug/ft · s	pascal second (Pa · s)	4.788026	E + 01
slug/ft^3	kilogram per cubic metre (kg/m^3)	5.153788	E + 02
statampere	ampere (A)	3.335640	E – 10
statcoulomb	coulomb (C)	3.335640	E – 10
statfarad	farad (F)	1.112650	E – 12
stathenry	henry (H)	8.987554	E + 11
statmho	siemens (S)	1.112650	E – 12
statohm	ohm (Ω)	8.987554	E + 11
statvolt	volt (V)	2.997925	E + 02
stere	cubic metre (m^3)	1.000000	*E + 00
stilb	candela per square metre (cd/m^2)	1.000000	*E + 04
stokes (kinematic viscosity)	metre squared per second (m^2/s)	1.000000	*E – 04
therm	joule (J)	1.055056	E + 08

ton (assay)	kilogram (kg)	2.916667	E – 02
ton (long, 2 240 lb)	kilogram (kg)	1.016047	E + 03
ton (metric)	kilogram (kg)	1.000000	*E + 03
ton (nuclear equivalent of TNT)	joule (J)	4.184	E + 09
ton (refrigeration)	watt (W)	3.516800	E + 03
ton (register)	cubic metre (m^3)	2.831685	E + 00
ton (short, 2 000 lb)	kilogram (kg)	9.071847	E + 02
ton (long)/yd^3	kilogram per cubic metre (kg/m^3)	1.328939	E + 03
ton (short)/h	kilogram per second (kg/s)	2.519958	E – 01
ton-force (2 000 lbf)	newton (N)	8.896444	E + 03
tonne	kilogram (kg)	1.000000	*E + 03
torr (mm Hg, 0°C)	pascal (Pa)	1.33322	E + 02
unit pole	weber (Wb)	1.256637	E – 07
W · h	joule (J)	3.600000	*E + 03
W · s	joule (J)	1.000000	*E + 00
W/cm^2	watt per square metre (W/m^2)	1.000000	*E + 04
W/in^2	watt per square metre (W/m^2)	1.550003	E + 03
yard	metre (m)	9.144000	*E – 01
yd^2	square metre (m^2)	8.361274	E – 01
yd^3	cubic metre (m^3)	7.645549	E – 01
yd^3/min	cubic metre per second (m^3/s)	1.274258	E – 02
year (calendar)	second (s)	3.153600	E + 07
year (sidereal)	second (s)	3.155815	E + 07
year (tropical)	second (s)	3.155693	E + 07

Table C-2. Temperature conversion formulae

To convert from	*to*	*Use formula*
Celsius temperature ($t°_C$)	Kelvin temperature (t_K)	$t_K = t°_C + 273.15$
Fahrenheit temperature ($t°_F$)	Celsius temperature ($t°_C$)	$t°_C = (t°_F - 32)/1.8$
Fahrenheit temperature ($t°_F$)	Kelvin temperature (t_K)	$t_K = (t°_F + 459.67)/1.8$
Kelvin temperature (t_K)	Celsius temperature ($t°_C$)	$t°_C = t_K - 273.15$
Rankine temperature ($t°_R$)	Kelvin temperature (t_K)	$t_K = t°_R/1.8$

ATTACHMENT E. PRESENTATION OF DATE AND TIME IN ALL-NUMERIC FORM

1. Introduction

The International Organization for Standardization (ISO) Standards 2014 and 3307 specify the procedures for writing the date and time in all-numeric form and ICAO will be using these procedures in its documents where appropriate in the future.

2. Presentation of date

Where dates are presented in all-numeric form, ISO 2014 specifies that the sequence year-month-day should be used. The elements of the date should be:

— our digits to represent the year, except that the century digits may be omitted where no possible confusion could arise from such an omission. There is value in using the century digits during the period of familiarization with the new format to make it clear that the new order of elements is being used;

— two digits to represent the month;

— two digits to represent the day.

Where it is desired to separate the elements for easier visual understanding, only a space or a hyphen should be used as a separator. As an example, 25 August 1983 may be written as:

19830825 or 830825

or 1983-08-25 or 83-08-25

or 1983 08 25 or 83 08 25.

It should be emphasized that the ISO sequence should only be used where it is intended to use an all-numeric presentation. Presentations using a combination of figures and words may still be used if required (e.g. 25 August 1983).

3. Presentation of time

3.1 Where the time of day is to be written in all-numeric form, ISO 3307 specifies that the sequence hours-minutes-seconds should be used.

3.2 Hours should be represented by two digits from 00 to 23 in the 24-hour timekeeping system and may be followed either by decimal fractions of an hour or by minutes and

seconds. Where decimal fractions of an hour are used, the normal decimal separator should be used followed by the number of digits necessary to provide the required accuracy.

3.3 Minutes should likewise be represented by two digits from 00 to 59 followed by either decimal fractions of a minute or by seconds.

3.4 Seconds should also be represented by two digits from 00 to 59 and followed by decimal fractions of a second if required.

3.5 Where it is necessary to facilitate visual understanding a colon should be used to separate hours and minutes and minutes and seconds. For example, 20 minutes and 18 seconds past 3 o'clock in the afternoon may be written as:

152018 or 15:20:18 in hours, minutes and seconds

or 1520.3 or 15:20.3 in hours, minutes and decimal fractions of a minute

or 15.338 in hours and decimal fractions of an hour.

4. Combination date and time groups

This presentation lends itself to a uniform method of writing date and time together where necessary. In such cases, the sequence of elements year-month-day-hour-minute-second should be used. It may be noted that not all the elements need be used in every case - in a typical application, for example, only the elements day-hour-minute might be used.